INDOOR AIR QUALITY ASSESSMENT

Petersham Town Office Building
3 South Main Street
Petersham, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of the Petersham Board of Health, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Petersham Town Office Building (PTOB), 3 South Street, Petersham, Massachusetts. Concerns about odors detected in the town selectmen's office prompted the request. On July 2, 2004, a visit was made to this building by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment.

The PTOB is a two-story, brick exterior structure originally constructed as a four room school. The building has been used as town offices since the early 1900s. The second floor houses the police department and one town office. The first floor contains the selectmen's and treasurer's offices. The basement is a dirt floor space that is unoccupied. Windows appear to be original wooden sash windows and are openable throughout the building. Window-mounted air conditioners were observed in some office windows. The floors are made of hardwood.

Methods

BEHA staff performed visual inspection of building materials for water damage and/or microbial growth. Moisture content of porous building materials was measured with a Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe. Air tests for carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

The PTOB has an employee population of 4 and is visited by approximately 25 to 30 people daily. Tests were taken during normal operations and results appear in Table 1.

Discussion

Ventilation

It can be seen from the Table that carbon dioxide levels were below 800 parts per million (ppm) in all occupied areas, indicating adequate ventilation in the building at the time of the assessment. Carbon dioxide levels in the building would be expected to be higher during winter months, when windows are closed.

No mechanical ventilation systems exist in the building. Each room has a gas-fueled heater. The sole source of fresh air is through openable windows. With the lack of supply and general exhaust ventilation, pollutants that exist in the interior space can build up and lead to indoor air quality and comfort complaints.

The building was configured in a manner to use cross-ventilation to provide comfort for building occupants. The PTOB is equipped with windows on opposing exterior walls. This design allows for airflow to enter an open window, pass through a room, through the open hallway door, enter the hallway, pass through the opposing room's hallway door, into the opposing room and exit the building on the leeward side (opposite the windward side) (Figure 1). With all windows and hallway doors open, airflow can be maintained in a building regardless of the direction of the wind. The system fails if the windows or hallway doors are closed (Figure 2).

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings ranged from 71^{o} F to 75^{o}F, which were within the BEHA recommended comfort guidelines in occupied areas. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o}F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, temperature control is often difficult in an old building without a mechanical ventilation system.

The relative humidity ranged from 59 to 61 percent in occupied areas, which was slightly above or near the upper end of the BEHA recommended comfort range (Table 1). The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Please note relative humidity in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

During the course of the assessment, building occupants expressed concerns about mold in the town selectmen's office. The floor of the selectmen's office was covered with wall-to-wall carpet installed on a foam rubber pad (Picture 1). An odor was detected in this area of the floor.

Moisture is introduced into the interior of the PTOB through basement windows that are opened in the summer (Picture 2). As relative humidity levels increase indoors, porous building materials, such a wood and carpeting, can absorb moisture. The moisture content of wood and carpeting can fluctuate with increases/decreases in indoor relative humidity. In an effort to ascertain moisture content of carpeting and the underlying floor, a Delmhorst probe was inserted into the surface of carpet, through the padding and into the surface of the town selectmen's office wooden floor. The Delmhorst probe was set to sound a signal when a moisture reading of $\geq$ 15 percent in wood was detected.

The building was evaluated on a sunny day, with an outdoor temperature of 74 ^{o} F and relative humidity of 65 percent. No active leaks were observed and no visible moisture was noted on walls. Relative humidity indoors was measured at 60 percent in the town selectmen's office (Table 1). Moisture measurements taken through the carpet to the wooden floor ranged from 16 to 45 percent. These measurements indicate that the wood surface below the foam rubber was moistened. This condition is likely attributable to the installation of the carpet and more importantly, the foam rubber pad on the floor. In this instance the foam rubber pad was glued to the floor, creating a vapor barrier which prevented air and water vapor movement. Without air and water vapor movement, the floor slats cannot dry since moisture is trapped between the foam rubber pad and underlying floor.

A number of conditions may have contributed to the accumulation of moisture between the floor and foam rubber pad over the past several years:

- When an air conditioned space (the town selectmen's office) is adjacent to a non-conditioned space (the dirt floor basement), measures to separate each space using adequate insulation is necessary to prevent condensation on shared surfaces (e.g., the wood floor). The floor beneath the town selectmen's office had insulation removed, exposing the underside of the floor, making it prone to condensation generation, particularly in hot, humid weather with the window-mounted air conditioner activated.
- The basement is subject to water penetration through its foundation in the southwest corner. Moist weather tends to travel in a northeasterly track up the Atlantic coast

towards New England (Trewartha, G.T., 1943). Wet weather systems generally produce south/southwesterly winds, which will expose the south and west facing walls to driving rain on a consistent basis, unlike the east and north walls. The basement consists of flagstone walls (Picture 3) with a dirt floor, which would allow accumulated surface water (pooling rain) on the exterior of the building to readily enter the basement. In order to prevent rainwater accumulation against the flagstone foundation, a tarmac apron was installed along the south and west walls. Over time, the apron has separated from the granite sill of the building, creating a seam on the west wall (Picture 4). In addition, a crack has formed in the corner of the west/south walls (Picture 5). The south wall base has a similar apron that is overgrown with grass and other plants. Over time, the south wall apron has become undermined and is sloped towards the building (Picture 6), which directs rainwater to pool in the foundation/ tarmac seam which subsequently penetrates into the basement the its wall. An additional water source in this general area is a downspout at this corner, which empties at the southwest corner of the building onto the tarmac. The effects of increased water penetration into the southwest corner is demonstrated by extensive repairs to rotted floor pillars and beams in the basement in this corner pf the PTOB area.

- According to town selectmen, the windows in the basement are opened in the spring and closed in the fall to provide ventilation for the basement. This practice may have increased water damage in the basement due to the excessively hot, humid weather that persisted in Massachusetts for more than 14 days during the month of August 2003 (The Weather Underground, 2003). This hot, humid weather would tend to wet soil and foundation stone from accumulation of condensation. Condensation is the collection of moisture on a surface that has a temperature below the dew point. The dew point is a temperature that is determined by air temperature and relative humidity. For example, at a temperature of 85°F and relative humidity of 90 percent, the dew point for water to collect on a surface is approximately 82°F. Therefore, if a surface has a temperature under 83°F, water vapor will form droplets on that surface. Surfaces below grade that are in contact with earth tend to be substantially cooler than the air temperature, making them prone to generating condensation. Once condensation moistens a material that can support fungal growth for an extended period of time, mold growth may occur.

Each of these conditions, in combination with high ambient temperature during the summer, increased relative humidity and possible water sources within the basement, may contribute to moistening of porous materials. The American Conference of Governmental Industrial Hygienists (ACGIH) and the US Environmental Protection Agency (US EPA) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (ACGIH, 1989; US EPA, 2001). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to porous materials is not recommended.

In order to explain how mold and associated odors/particulates in the basement can migrate into occupied areas, the following concepts must be understood:

- Heated air in occupied areas will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.

- As the heated air rises, negative pressure is created, which draws cold air to the heat source.
- Airflow created by the stack effect, drafts or wind-driven air can draw airborne particulates into the air stream (i.e., from the basement).
- The opening of the door to the basement at the base to the town selectmen's office can provide a pathway for air to travel from the basement to the upper floors.

Each of these concepts has an influence on the movement of basement odors and/or other particulates up the stairwell. In order to control possible mold growth, water penetration into the basement area must be minimized. Control of water penetration through the foundation can be limited by tightening up the building envelope and reestablishing proper drainage around the building foundation.

Other Concerns

Filters in window-mounted air conditioners had significant amounts of accumulated dust and debris. The purpose of air conditioner filters is to remove particulate matter from air drawn into the units. Air conditioner filters need to be cleaned on a regular basis in order to maximize the efficiency of the filter. If not cleaned regularly, the filter can become saturated with dust and become a source of aerosolized particulates when the air conditioner is operating.

A photocopier is located in the main office. Volatile organic compounds (VOCs) and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, D., 1992). No local exhaust ventilation was present in this area to help reduce excess heat and odors.

Conclusions/Recommendations

In order to address the conditions listed, the recommendations made to improve indoor air quality in the building are divided into short-term and long-term corrective measures. The **short-term** recommendations can be implemented as soon as practicable. **Long-term** measures are more complex and will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1. Remove carpet and padding from the selectman's office.
2. Clean residue from floor beneath carpet and allow to air dry. Once dry, refinish the floor during temperate weather.
3. Remove rotten timber and other accumulated debris from the basement.
4. Install weather stripping and a door sweep on both the attic and basement doors to limit air movement into occupied areas.
5. To prevent moisture penetration into the basement, the following actions should be considered:
    a) Extend downspout and reestablish the grade of the tarmac apron to drain rainwater from the foundation.
    b) Seal the crack in the foundation on the southwest corner of the building and the spaces on the western and southern exterior walls between the foundation/tarmac junctions with an appropriate sealing compound.

c) Remove foliage to no less than five feet from the foundation.

d) Improve the grading of the ground away from the foundation at a rate of 6 inches per every 10 feet (Lstiburek, J. & Brennan, T.; 2001).

e) Install a water impermeable layer on ground surface (clay cap) to prevent water saturation of ground near foundation (Lstiburek, J. & Brennan, T.; 2001).

6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

7. Install filters in window-mounted air conditioning units that conform to manufacturer's instructions. Clean the window-mounted air conditioners before and after activation in accordance with manufacturer's instructions.

8. Consider installing local exhaust ventilation in the photocopier area.

9. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

10. Consult "Mold Remediation in Schools and Commercial Buildings" published by the US EPA (2001) for further information on mold. Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.

Long Term Recommendations

1. In order to aid in the prevention of water vapor accumulation in the basement, consideration should be given to installing a low speed exhaust fan in one of the basement windows. The fan should be operated during hot, humid weather to exhaust water vapor and draw dry air from the upper occupied levels during summer months.
2. To provide insulation during the winter, consult a building engineer on the appropriate method to insulate the floor to prevent moisture accumulation.

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Figure 1 **Cross Ventilation in a Building Using Open Windows and Doors**

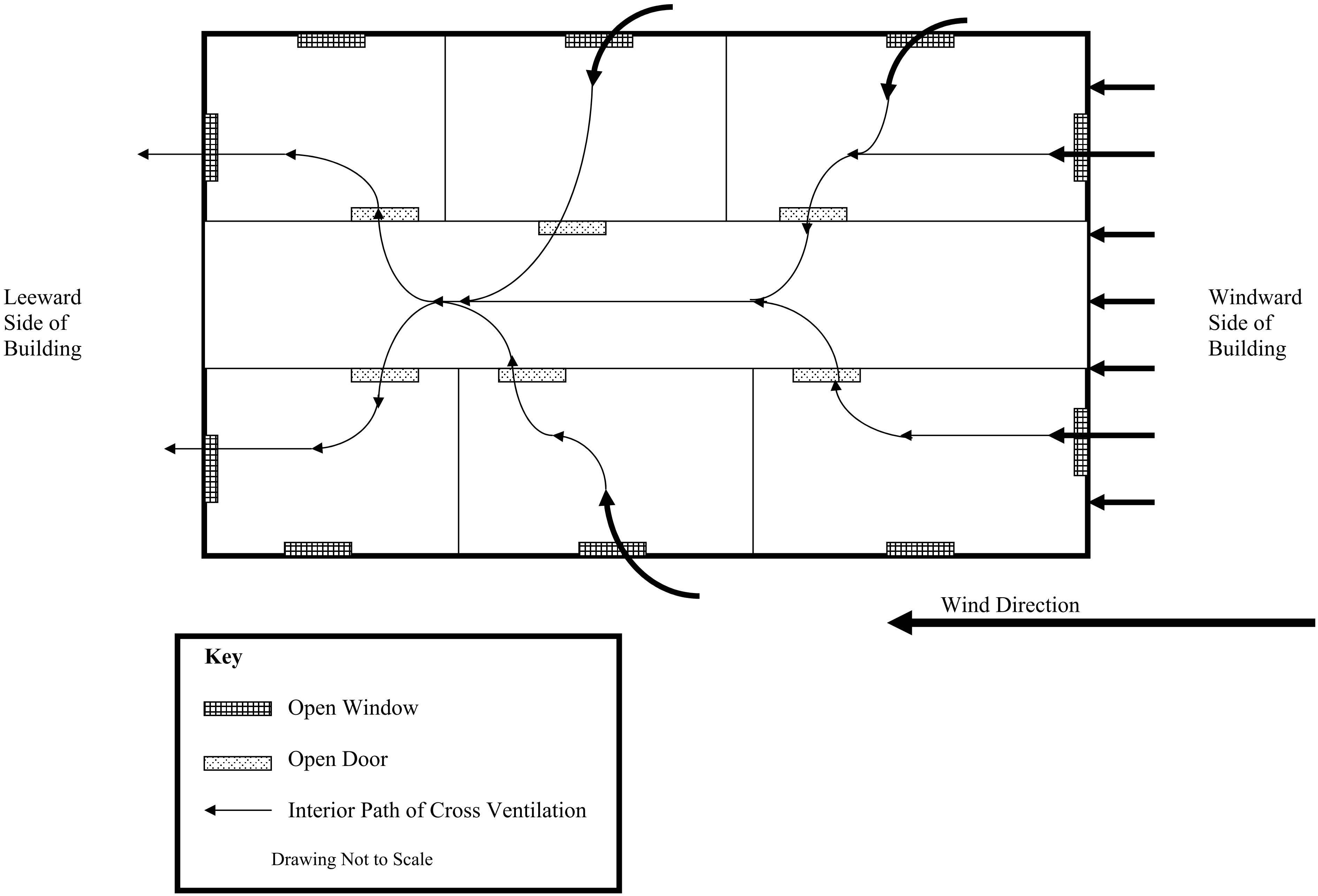
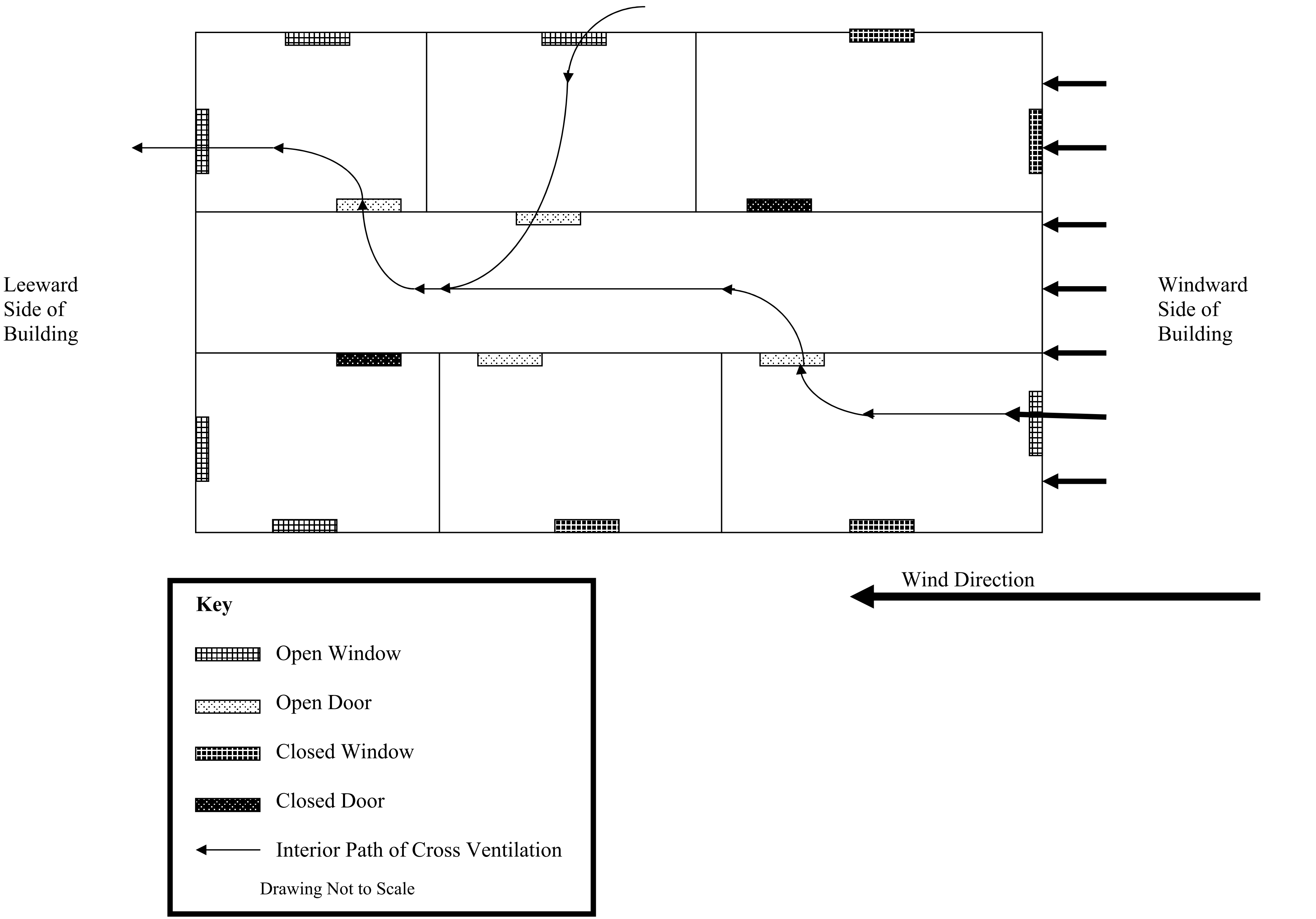


Figure 2 **Inhibition of Cross Ventilation in a Building with Several Windows and Doors Closed**



Picture 1

Wall-To-Wall Carpet Installed on a Foam Rubber Pad in Selectmen's Office

Picture 2

Open Window to Air out the Basement during Warm Weather

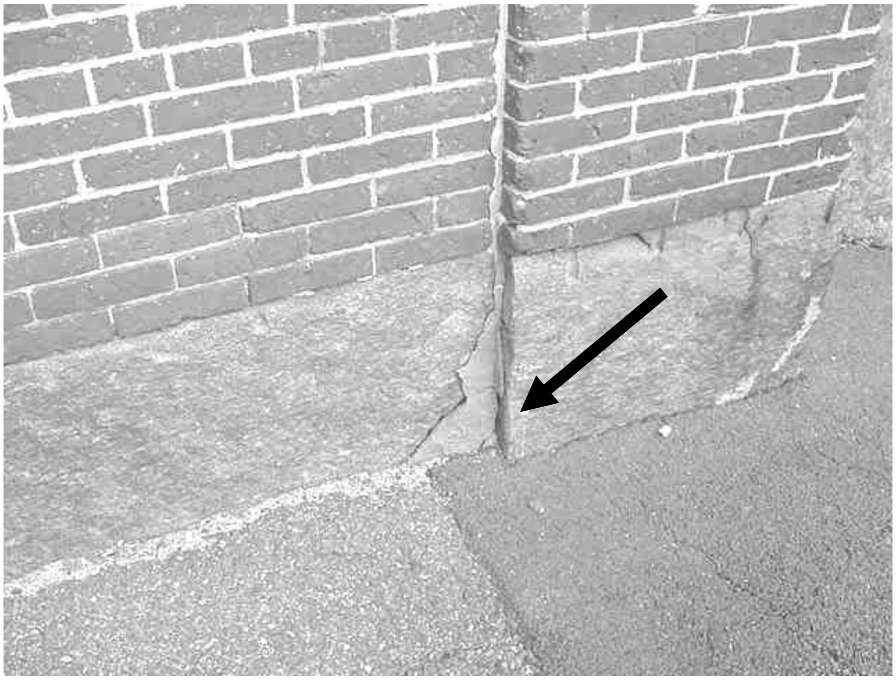
Picture 3

The Flagstone Walls of the Basement

Picture 4

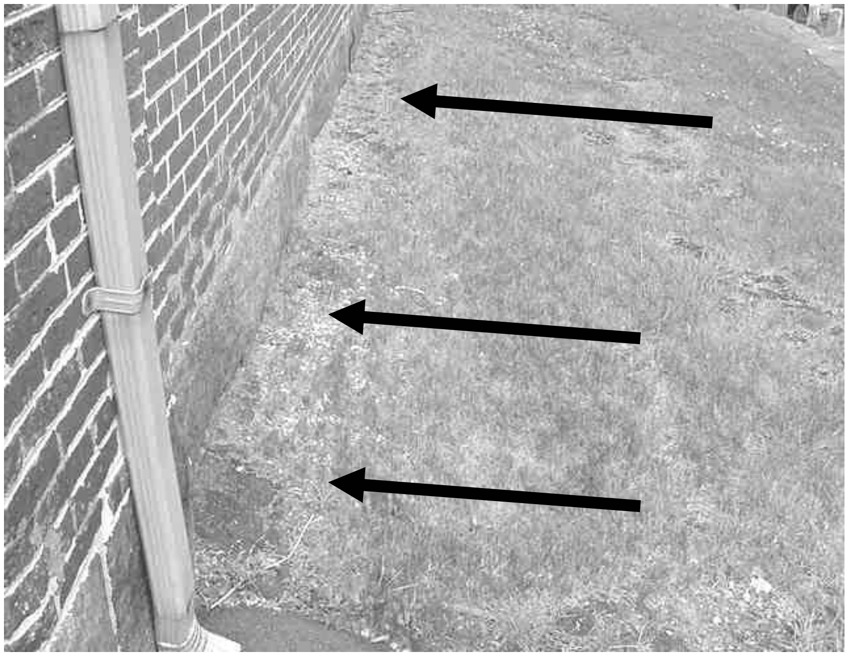
Seam between Apron and Granite Sill of the South Exterior Wall

Picture 5



Crack at the Corner of the South Exterior Wall

Picture 6



Buried South Exterior Wall Apron Sloping Towards the Building

TABLE 1

Indoor Air Test Results

Petersham Town Office Building, 3 South Street, Petersham, Massachusetts

July 2, 2004

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Outside (Background)	375	74	65					
Selectmen's Office	475	75	60	1	Y	N	N	• Moisture sampling through carpet 16-45% • Window-mounted air conditioner
Assessor's Office	473	75	59	0	Y	N	N	
2nd floor open office	432	74	60	0	Y	N	N	
Police hallway	436	71	61	0	Y	N	N	
Attic	416	81	52	0	Y	N	N	
Dirt Floor Basement	448	69	70	0	Y	N	N	• Window open

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%